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Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools

MarLIN – Marine Life Information Network
Marine Evidence–based Sensitivity Assessment (MarESA) Review

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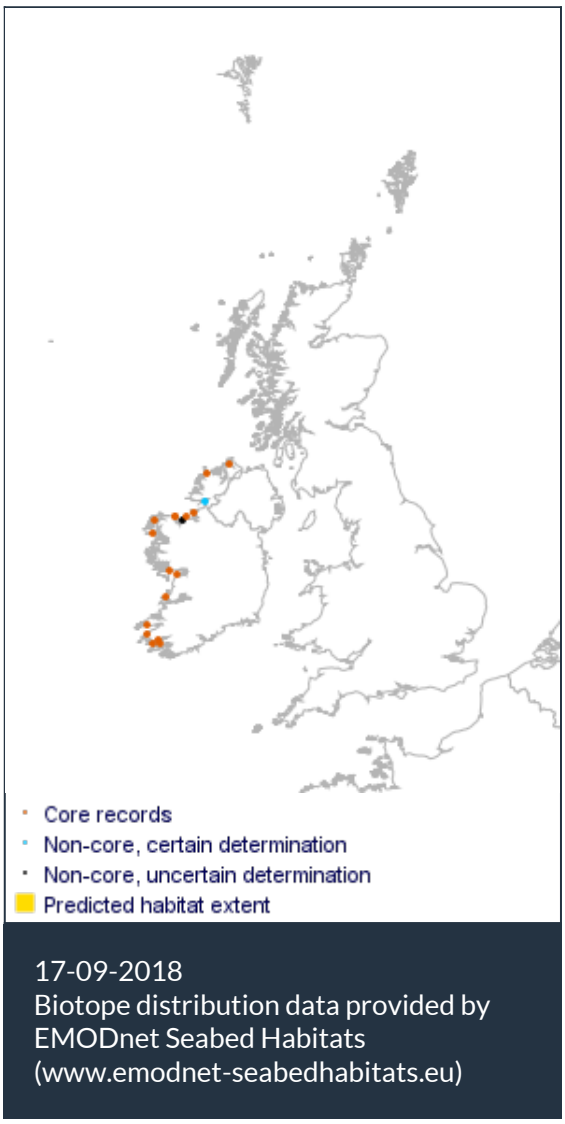

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A1.4112	Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools
JNCC 2015	LR.FLR.Rkp.Cor.Par	Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools
JNCC 2004	LR.FLR.Rkp.Cor.Par	Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools
1997 Biotope	LR._.Rkp.Cor.Par	Coralline crusts and *Paracentrotus lividus* in shallow eulittoral rockpools

Description

Shallow and relatively smal rockpools throughout the eulittoral zone on very exposed to exposed shores, characterized by a covering of encrusting coralline algae on which *Corallina officinalis* forms

a dense turf. The bottom of these pools can be covered in coarse gravel and cobbles. In south and west Ireland these coralline pools may be dominated by the sea urchin *Paracentrotus lividus* and the seaweed diversity is generally low due to the grazing pressure of *Paracentrotus lividus*, the top shells *Gibbula cineraria* and *Gibbula umbilicalis*, and winkles such as *Littorina littorea*. Within the pools, pits and crevices are often occupied by the anemone such as *Actinia equina* and *Anemonia viridis* and small individuals of the mussel *Mytilus edulis*. The siphonous green seaweed *Codium* spp. can also be present along with the wrack *Himanthalia elongata* and the brown seaweed *Leathesia difformis* and the filamentous red seaweed *Ceramium* spp. The barnacle *Semibalanus balanoides* is either absent or occurs at low abundance in these rockpools, presumably due to the grazing pressure on the larval stage and the predation pressure from the whelk *Nucella lapillus*. Soft bedrock, such as limestone, allows *P.aracentrous lividus* to bore into the rock (JNCC, 2015)

Depth range

Upper shore, Mid shore, Lower shore

Additional information

-

Listed By

- none -

Further information sources

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and characterizing species are taken from Connor *et al.* (2004). The biotope describes shallow and relatively small rockpools throughout the eulittoral zone on very exposed to exposed shores, characterized by a covering of encrusting coralline algae on which *Corallina officinalis* forms a dense turf. The coralline crusts and turfs of *Corallina officinalis* are considered the key characterizing and structuring species within the biotope and the sensitivity assessments focus on these species (although information on coralline crusts is limited). The bottom of these pools can be covered in coarse gravel and cobbles. In south and west Ireland these coralline pools may be dominated by the sea urchin *Paracentrotus lividus* and the seaweed diversity is generally low due to the grazing pressure of *Paracentrotus lividus*, the top shells *Gibbula cineraria* and *Gibbula umbilicalis*, and winkles such as *Littorina littorea*. Grazing is a key factor structuring the biotope and the loss of grazers would alter the algal assemblage within the pools (Robles, 1982,; Albrecht, 1998; Palacín et al., 1998; Sala *et al*., 1998). The sensitivity of grazers is considered within the sensitivity assessments with particular emphasis on littorinids and *Paracentrotus lividus*. Within the pools, pits and crevices are often occupied by the anemone such as *Actinia equina* and *Anemonia viridis* and small individuals of the mussel *Mytilus edulis*. The siphonous green seaweed *Codium* spp. can also be present along with the wrack *Himanthalia elongata* and the brown seaweed *Leathesia difformis* and the filamentous red seaweed *Ceramium* spp. These common rocky shore species while contributing to species diversity and ecological function within the biotope are not considered to be key to the biotope and are therefore not specifically considered within the assessments. Soft bedrock, such as limestone, allows *Paracentrotus lividus* to bore into the rock and is therefore a key component of the biotope and is assessed where the pressure may lead to alterations in the substratum.

Resilience and recovery rates of habitat

Where this biotope is impacted by pressures, recovery of the key structuring and characterizing species *Corallina officinalis* will require either regrowth from surviving holdfast or basal crusts or recolonization by propagules. The crustose holdfast or base is perennial and grows apically (continuous growth at tips), similar to encrusting corallines such as *Lithothamnia* sp. The basal crust may grow continuously until stimulated to produce fronds (Littler & Kauker 1984; Colhart & Johanssen 1973). Littler & Kauker (1984) suggest that the crustose bases are an adaptation to resist grazing and desiccation whereas the fronds are adapted for higher primary productivity and reproduction. The basal crusts are tougher than the upright fronds (requiring a pressure of 94 g/mm^2 to penetrate, compared to 43 g/mm^2 respectively). Regeneration of the basal crusts provides a more rapid route to recovery than recolonization. Experiments in the intertidal in southern California found that areas scraped back to crusts recovered four times more rapidly than sterilised plots where the crusts were removed (Littler & Kauker, 1994).

In culture *Corallina officinalis* fronds exhibited an average growth rate of 2.2 mm/month at 12 and 18 °C. Growth rate was only 0.2 mm/month at 6 °C and no growth was observed at 25 °C (Colhart & Johanssen 1973). Similarly Blake & Maggs (2003) observed much higher growth rates of 2 mm/month over 6 months starting from September in *Corralina officinalis* grown in Strangford Lough (Northern Ireland) at 5 and 10m depth, these rates are similar to those observed by Andrake & Johansen, (1980) in winter in New Hampshire. The evidence for growth rate suggests that to achieve a height of 10 cm the turf would be at least 4 years old (probably older as higher

temperatures appear to slow growth. A lower level turf of, for example 5 cm, could theoretically be achieved within 2 years.

Where the bases are removed, recovery will depend on recolonization. Areas that are cleared during the reproductive period have the potential to be rapidly colonized. *Corallina officinalis* was shown to settle on artificial substances within 1 week of their placement in the intertidal in New England summer (Harlin & Lindbergh, 1977). However, settlement plates laid out in the autumn were not recolonized until the next spring. In the lower rocky intertidal in southern California dominated by *Corallina officinalis* with foliose overstorey algae present, Littler & Kauker (1984) experimentally cleared plots and followed the recovery for 12 months. Some areas were scraped allowing the basal crusts to remain whereas others were completely sterilised (removal of all material and surfaces then scorched with a blow torch to remove bases). In scraped plots up to 15% cover of *Corallina officinalis* fronds returned within 3 months after removal of fronds and all other epiflora/fauna (Littler & Kauker, 1984) while in sterilized plots (all basal crusts removed) appearance of articulated fronds occurred 6 months following clearance. At the end of the 12 month observation period *Corallina officinalis* cover had increased to approximately 18% in plots where basal crusts remained and to approximately 10% in sterilised plots. Similarly Bamber & Irving (1993) reported that new plants grew back in scraped transects within 12 months, although the resistant crustose bases were probably not removed.

Once established turfs of *Corallina* spp. can persist for a long time, surveys of rocky intertidal ledges at Hinkley point, Somerset in England have found that the patches mapped in the 1980s (Bamer & Irving, 1993) had not changed position when resurveyed 18 years later (Burdon *et al*., 2009). It has been speculated but not definitively demonstrated that turf-forming algae and canopy forming algae may represent alternate stable states on temperate rocky shores and a shift in balance to the alternate state may prevent recovery. Some potential mechnaisms for inhibition of canopy forming species are space pre-emption by turfs that prevent recruitment of taller algae (Perkol-Finkel & Airoldi, 2010, Kennellyy 1987) due to the coverage of suitable rock surfaces and the presence of sediments within the turf (Airoldi, 2003). Clearance experiments on rocky, intertidal shores in Southern California (Sousa, 1979) found that *Ulva* species which have a longer reproductive season could colonize cleared areas preventing the establishment of perennial red algae. However grazing by crabs removed the green algae (Sousa, 1979), highlighting the potential importance of grazers, particularly littorinids, to the reestablishment of this biotope.

Although ubiquitous in marine coastal systems little is understood about the taxonomy, biology and ecology of this taxa (Littler & Littler, 2013). Coralline crust is a generic term that in UK biotopes refers to nongeniculate (crustose) species from the family Corallinacea that could include *Lithophyllum incrustans* which is noted to form thick crusts in tidepools, especially in the south west (Adey & Adey, 1973), *Lithothamnion* spp. and *Phymatolithon* spp. Throughout the sensitivity assessments the term coralline crust is used to refer to the Corallinacea within the biotope. Due to the lack of evidence for species the assessments are generic, although species specific information is presented where available.

A number of papers by Edyvean & Ford (1984a & b; 1986;1987) describe aspects of reproduction and growth of encrusting coralline, *Lithophyllum incrustans*. Studies by Edyvean & Forde (1987) in populations of *Lithophyllum incrustans* in Pembroke south-west Wales suggest that reproduction occurs on average early in the third year. Reproduction may be sexual or asexual. Populations release spores throughout the year but abundance varies seasonally, with the populations studied in Cullercoats Bay, and Lannacombe Bay (North East and South West England, respectively) producing less spores in the summer. Spore release is initiated by changes in temperature or

salinity (see relevant pressure information) at low tide so that spore dispersal is restricted to within the tide pool enhancing local recruitment. Spore survival is extremely low with only a tiny proportion of spores eventually recruiting to the adult population (Edyvean & Ford, 1986). The spores are released from structures on the surface called conceptacles, these are formed annually and subsequently buried by the new layer of growth. Plants can be aged by counting the number of layers of conceptacles. Edyvean & Ford (1984a) found that the age structure of populations sampled from Orkney (Scotland) Berwick (northern England) and Devon (England) were similar, mortality seemed highest in younger year classes with surviving individuals after the age of 10 years appear relatively long-lived (up to 30 years). In St Mary's Northumberland, the population was dominated by the age 6-7 year classes (Edyvean & Ford, 1984a). Growth rates were highest in young plants measured at Pembroke (south-west Wales) with an approximate increase in diameter of plants of 24 mm in year class 0 and 155 mm in year 1 and slowing towards an annual average horizontal growth rate of 3mm/year (Edyvean & Ford, 1987).

Some repair of damaged encrusting coralline occurs through vegetative growth. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the Sea Empress spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area. Recolonization by propagules is an important recovery mechanism, Airoldi (2000) observed that encrusting coralline algae recruited rapidly on to experimentally cleared subtidal rock surfaces in the Mediterranean Sea, reaching up to 68% cover in 2 months. As encrusting corallines are sensitive to desiccation (Dethier, 1994) it should be noted that these subtidal habitats are probably more favourable for recruitment, growth and survival than intertidal rock pools.

In some areas the urchin *Paracentrotus lividus* is a key characterizing species of this biotope (Connor *et al*., 2004). In rock pools generally low mortalities from predators are observed in the first four years (Crapp & Willis, 1975) although mortality increases as the individual ages, the maximum longevity may exceed 13 years (Delmas, 1992). In some instances studied populations have been relatively stable but significant annual variations in populations are more usual (Boudouresque & Verlaque, 2001). For example, over 40 years of monitoring populations in Loch Hyne have varied by four orders of magnitude, mostly in the absence of fishing (Andrew *et al*., 2002 and references therein). Adult urchins are mobile and during the daily activity peak may travel 40 cm/hour, although movement may be limited in areas with high water movements and in very exposed conditions adults may remain in burrows (Boudoresque & Verlaque, 2001). Migration of adults may therefore provide a mechanism of recovery for impacted populations. In areas where *Paracentrotus lividus* occurred in high densities and was experimentally removed, migration by foraging adults had led to a recovery in 2 months (Kempf, 1962), however, in low density populations very little migration was observed (Palacin *et al*., 1997).

The reproductive cycle varies between localities but typically there are one or two seasonal spawning peaks (although low-level larval production may occur year round) these are influenced by a number of factors including food supply, temperature and day length (Boudouresque & Valerque, 2001 and references therein). The planktonic lifespan of the larvae is of 20–40 days (Pedrotti, 1993), allowing this species to disperse over great distances. Despite annual supply of larvae, successful recruitment may be episodic and populations may show missing size cohorts, or those that are under or over-represented (Delmas, 1992). Episodic recruitment accounts for some of the population variations observed (Boudouresque & Verlaque, 2001).

Resilience assessment. No direct evidence was found for the age of individual *Corallina* crusts,

longevity of turfs or the time to recover from basal crusts or sterilised plots to a full dense cover. New crustose bases may recruit and develop quickly but the formation of new fronds from these bases and recovery of original cover may take longer. Once a coralline turf has developed it will probably be colonized by epiphytic invertebrates such as harpacticoids, amphipods and isopods relatively quickly from the surrounding area. Therefore, the biotope would be recognizable once the coralline turf has regrown, which is likely to be quite rapid if the resistant crustose bases remain. The clearance experiments by Littler & Kauker (1984) suggest that recovery of a dense turf cover whether basal crusts remained or were totally removed would require more than 2 years. Presumably, as crusts can grow in all directions percentage cover is not a linear function and that gap closure would speed up with greater cover.

Recruitment of associated species of red algae is probably equally rapid, and once the algal turf has developed most of the epiphytic invertebrates would colonize quickly. The ephemeral green algae associated with the biotope are opportunist colonizers of gaps and would be expected to recover within a year. Littorinds and *Paracentrotus lividus* could recover through migration but where populations are removed over a larger area recolonization by larvae would be required. Recruitment through larvae may be episodic and recovery to former population structure may require > 2 years. More detailed information on recovery of associated species can be found in the information for biotopes where these are the key characterizing species. Resilience of the biotope is assessed as 'High' where resistance is 'High' (no significant impact) or 'Medium' (where <25 % of *Paracentrotus lividus* and *Corallina officinalis* fronds are removed and bases remain) based on regrowth from the basal crusts and vegetative growth from surrounding turfs and repair, and migration or recolonization of associated species. Where resistance is 'Low' or 'None' then resilience is assessed as 'Medium', between 2 -10 years but towards the lower end of that range for *Corallina officinalis* and *Paracentrotus lividus* and the associated species. Where perturbations have a large spatial footprint with widespread removal of crusts and grazers over a large area then the development of an alternate state emerging with dominance by canopy forming algae is a possibility. In such an instance recovery could take much longer and depend on active management or further perturbations. No evidence was found however to determine when such shifts might occur.

NB: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Species found in the intertidal are exposed to extremes of high and low air temperatures during

periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter, air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in this intertidal biotope are therefore generally adapted to tolerate a range of temperatures, although the timing of site-specific factors such as low tides will influence local acclimation.

The key characterizing species, *Corallina officinalis* has a cosmopolitan distribution (Guiry & Guiry, 2015) and throughout its range experiences wide variation in temperatures (although local populations may be acclimated to the prevailing thermal regime). Littler & Kauker (1984) suggested that the crustose bases of *Corallina officinalis* are more resistant of desiccation or heating than fronds. Severe damage was noted in *Corallina officinalis* fronds as a result of desiccation during unusually hot and sunny weather in summer 1983. An abrupt increase in temperature of 10°C caused by the hot, dry 'Santa Anna' winds (between January -and February) in Santa Cruz, California resulted in die back of several species of algae exposed at low tide (Seapy & Littler, 1982). Lüning (1990) reported that *Corallina officinalis* from Helgoland survived one week exposure to temperatures between 0°C and 28°C. Encrusting corallines are also considered to have a high tolerance for increases in temperature at the pressure benchmark as these are widespread species within the intertidal. Latham (2008) investigated the effects of temperature stress on *Corallina officinalis* through laboratory tests on samples collected in the Autumn in Devon, England from rock pools. Samples were kept at 15°C for three days and then exposed to temperatures of 5, 15, 20, 25 and 30°C (the normal range of temperature experienced was suggested to be between 5 and 15°C). At 35°C the *Corallina was* completely bleached after 3 days with a sample kept at 30°C beginning to bleach. After 7 days (the end of the experiment) the sample kept at 30°C was partially bleached. Samples kept at 5, 15, 20 and 25°C showed little change in chemicals produced in reaction to thermal stress and no bleaching suggesting the temperatures in that range had not induced stress reactions.

In an exceptionally hot summer (1983, with an increase of between 4.8 and 8.5 °C) Hawkins & Hartnoll (1985) observed no temperature bleaching of adult *Himanthalia elongata* (although some buttons were bleached) or other canopy forming species. However, understorey red algae showed more signs of damage with bleached *Corallina officinalis* and 'lithothamnia' observed around the edges of pools due to dessication. Occasional damaged specimens of *Palmaria palmata*, *Osmundea pinnatifida* and *Mastocarpus stellatus* were observed.

Boudouresque & Verlaque, (2001), reviewed the ecology of *Paracentrotus lividus*. They suggest that the species is particularly common in regions where winter water temperatures range from 10-15°C and summer temperatures from 18-25°C. Its northern limits correspond to 8°C winter and 28°C summer isotherms. In the English Channel, lower and upper lethal temperatures are 4°C to 29°C. Spawning may be initiated by temperature changes and seawater temperatures 13°C- 16°C may initiate spawning, where there are two spawning periods the first would occur as the temperature rises to a critical level and the second when it falls to that level although length of daylight may also be a cue (Boudouresque & Verlaque, 2001 and references therein).

Littorinid*s* are also key grazers within this biotope biotope. Laboratory studies suggest that adults of these species can tolerate temperature increases. The median upper lethal temperature limit in laboratory tests on *Littorina littorea*, *Littorina saxatilis* was approximately 35°C (Davenport & Davenport, 2005). The smaller species associated with the *Corallina officinalis* may be protected within fronds and accumulated sediments from changes in temperature although no direct evidence was found to assess sensitivity of these to increased temperatures.

Sensitivity assessment. Based on the global distribution of *Corallina officinalis* and the experiments by Latham (2008) which approximate to the pressure benchmark more than the observations of extreme events (Seapy & Littler, 1982, Hawkins & Hartnoll, 1985) it is suggested that *Corallina officinalis* would not be sensitive to either an acute or chronic increase in temperature at the pressure benchmark. Littler & Littler (1984) suggest that the basal crustose stage is adaptive as resisters of sand scour and wave shearing as well as physiological stressors such as desiccation and heating. Where these survive any increases in temperature above the pressure benchmark they would provide a mechanism for biotope recovery. The key grazing species *Paracentrotus lividus* and the littorinids have a broad temperature tolerance. The sensitivity of the biotope is based on the key characterizing *Corallina* turf and *Paracentrotus lividus* and littorinid grazers, but it should be noted that many of the associated species are considered to have 'High' resistance to changes in temperature at the pressure benchmark. Resistance of the biotope to both acute and chronic increases in temperature is considered to be 'High' and resilience is 'High' (by default) and the biotope is considered to be 'Not sensitive'. It should be noted that the timing of acute increases would alter the degree of impact and hence sensitivity. An acute change occurring on the hottest day of the year and exceeding thermal tolerances would lead to mortality.

Temperature decrease (local)	Low Q: High A: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Many intertidal species are tolerant of freezing conditions as they are exposed to extremes of low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer, air temperatures are much warmer than the sea. Species that occur in the intertidal are therefore generally adapted to tolerate a range of temperatures, with the width of the thermal niche positively correlated with the height of the shore (Davenport & Davenport, 2005).

Under extremely low temperatures, components of the community demonstrate tolerance. Lüning (1990) reported that *Corallina officinalis* from Helgoland survived 0°C when exposed for one week. New Zealand specimens were found to tolerate -4°C (Frazer *et al*., 1988). Lüning (1990) suggested that most littoral algal species were tolerant of cold and freezing. For example, the photosynthetic rate of *Chondrus crispus* recovered after 3hrs at -20°C but not after 6 hrs (Dudgeon *et al*., 1990). The photosynthetic rate of *Mastocarpus stellatus* higher on the shore fully recovered from 24 hrs at -20°C.

A series of experiments indicated that median lower lethal temperature tolerances for *Littorina saxatilis* and *Littorina littorea* were -16.4 and -13°C respectively (Davenport & Davenport, 2005).

Boudouresque & Verlaque, (2001), reviewed the ecology of *Paracentrotus lividus*. They suggest that the species is particularly common in regions where winter water temperatures range from 10-15°C and summer temperatures from 18-25°C. Its northern limits correspond to 8°C winter and 28°C summer isotherms. In the English Channel, lower and upper lethal temperatures are 4°C to 29°C. As this species is generally subtidal its tolerance for colder temperatures is predicted to be lower than other intertidal species (Davenport & Davenport, 2005). Populations in rockpool may be exposed to lethal temperatures in winter in intertidal rock pools.

Sensitivity assessment. Based on the characterizing *Corallina turf* and associated species, this biotope is considered to have 'High' resistance and 'High resilience (by default) to this pressure and is therefore considered to be 'Not sensitive'. The timing of changes and seasonal weather could

result in greater impacts on species. An acute decrease in temperature coinciding with unusually low winter temperatures may exceed thermal tolerances and lead to mortalities of the associated species although this would not alter the character of the biotope. Where this biotope is defined by the presence of the urchin *Paracentrotus lividus*, sensitivity to this pressure is considered greater where acute decreases in temperature occur in winter. Resistance of the biotope defined by *Paracentrotus lividus* is therefore assessed as 'Low' and resilience as 'Medium', sensitivity is therefore assessed as 'Medium'. The more precautionary assessment is presented in the sensitivity assessment table.

Salinity increase (local)	Low Q: Low A: NR C: NR	Medium Q: High A: Low C: Medium	Medium Q: Low A: Low C: Low

Local populations may be acclimated to the prevailing salinity regime and may therefore exhibit different tolerances to other populations subject to different salinity conditions and therefore caution should be used when inferring tolerances from populations in different regions. This biotope is found in full (30-35 ppt) salinity (Connor *et al*., 2004). Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity.

The characterizing species *Corallina officinalis* and crustose corallines are found in rockpools, such as this biotope, where salinities may fluctuate markedly during exposure to the air. Kinne (1971a) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons. Edyvean & Ford (1984b) suggest that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in rockpools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

Although present in Mediterranean coastal lagoons and Atlantic estuaries (Boudouresque & Verlaque, 2001) *Paracentrotus lividus* is sensitive to high salinities. Upper lethal salinities are 39-44 ppt for long-term exposure (Pastor, 1971; Allain, 1975; Le Gall *et al*., 1989). Young *Littorina littorea* inhabit rock pools where salinity may increase above 35 psu. Thus, the associated species may be able to tolerate some increase in salinity. *Mytilus edulis* is found in a wide range of salinities from variable salinity areas and mussels in rock pools are likely to experience hypersaline conditions on hot days. Newell (1979) recorded salinities as high as 42 psu in intertidal rock pools, suggesting that *Mytilus edulis* can tolerate high salinities.

Sensitivity assessment. No direct evidence was found to assess sensitivity to this pressure. Although some increases in salinity may be tolerated by the associated species present these are generally short-term and mitigated during tidal inundation. This biotope is considered, based on the salinity tolerance of *Paracentrotus lividus* and the distribution of *Corallina officinalis* on the mid to lower shore to be sensitive to a persistent increase in salinity to > 40 ppt. Resistance is therefore assessed as 'Low' and recovery as 'Medium' (following restoration of usual salinity). Sensitivity is therefore assessed as 'Medium'.

Salinity decrease (local)	Low Q: Medium A: Low C: Low	Medium Q: High A: Low C: Medium	Medium Q: Low A: Low C: Low

Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity. As this biotope is present in full salinity, the assessed change at the pressure benchmark is a reduction in salinity to a reduced regime (18-30 ppt).

Edyvean & Ford (1984b) suggest that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in tide pools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

In the Baltic, *Corallina officinalis* is confined to deeper waters as surface salinity decreases (Kinne, 1971a) suggesting that full salinity is required in the long-term although short-term fluctuations may be tolerated (although the thresholds of this tolerance are not clear). Kinne (1971a) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons, so that a decrease in salinity at the pressure benchmark would be predicted to lead to reduced growth. Although present in Mediterranean coastal lagoons and Atlantic estuaries (Boudouresque & Verlaque, 2001) *Paracentrotus lividus* is sensitive to low salinities. Lower lethal salinities are 15-20 ppt for long-term exposure (Allain, 1975; Pastor. 1971; Le Gall *et al*., 1989). An abrupt drop in salinity of 7 psu following an exceptional high rainfall event resulted in the estimated loss of 50% of *Paracentrotus lividus* from a brackish lagoon (salinity typically 30-38 psu) in Urbinu, Corsica (Fernandez *et al*., 2006). This event was coupled with higher turbidity's and siltation so that the effects cannot be ascribed to salinity changes alone.

Based on occurrence in estuaries it is clear that some of the species associated with this biotope have a high tolerance for this pressure. However, it should be noted that local populations may be acclimated to the prevailing salinity regime and may therefore exhibit different tolerances to other populations subject to different salinity conditions so that caution should be used when inferring tolerances from populations in different regions. *Ulva* species are considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Although some variation in salinity tolerance between populations of *Ulva intestinalis* have been found indicating that plants have some adaptation to the local salinity regime (Reed & Russell, 1979). *Littorina littorea* is found in waters of full, variable and reduced salinities (Connor *et al*., 2004) and so populations are considered tolerant of decreases in salinity at the pressure benchmark. *Mytilus edulis* is found in a wide range of salinities from variable salinity areas (18-35 ppt) such as estuaries and intertidal areas, to areas of more constant salinity (Connor *et al*., 2004). *Mytilus edulis* was recorded to grow in a dwarf form in the Baltic sea where the average salinity was 6.5psu (Riisgård *et al*., 1993).

Prolonged reduction in salinity, e.g. from full to reduced (18-30 ppt), is likely to reduce the species richness of the biotope due to loss of some intolerant invertebrates from the assemblage associated with the *Corallina officinalis* turf.

Sensitivity assessment. Although some daily changes in salinity may be experienced these will be mitigated during tidal inundation. This biotope is considered to be sensitive to a decrease in saliniyt at the pressure benchmark, based on the salinity tolerances of *Paracentrotus lividus* and *Corallina officinalis* distribution and the evidence from Kinne (1971). Resistance is therefore assessed as 'Low' and recovery as 'Medium' (following restoration of usual salinity). Sensitivity is therefore assessed as 'Medium'.

Water flow (tidal current) changes (local)	High Q: High A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Low

Corallina officinalis dominated biotopes are found in a range of flow rates *from* 'moderately strong' (0.5-1.5 m/s) to very 'weak' negligible) (Connor *et al*., 2004; Dommasnes, 1969) and the rock pool habitat of this biotope will provide some protection from water flows. Moderate water movement is beneficial to seaweeds as it carries a supply of nutrients and gases to the plants and removes waste products. However, if flow becomes too strong, plants may become displaced. Additionally, an increase to stronger flows may inhibit settlement of spores and remove adults or germlings. However, *Corallina officinalis* have a compact, turf forming growth which reduce water flow through turbulence and friction and are probably resistant to displacement by an increase in water flow. The coralline crusts characterizing this biotope are securely attached and as these are flat are subject to little or no drag.

The shallow burrows created by *Paracentrotus lividus* also provide some protection from dislodgement. Changes in water flow at the pressure benchmark may result in increased or decreased sediment deposition; these are not considered to alter the character of the biotope but may alter species richness of the small invertebrates associated with the turf.

Sensitivity assessment. The biotope is found across a range of flow rates, mid-range populations are considered to have 'High' resistance to a change in water flow at the pressure benchmark (although see sediment supply caveats). Resilience is assessed as 'High', by default, and the biotope is considered 'Not sensitive'.

Emergence regime changes	Medium Q: High A: Low C: Medium	High Q: High A: Low C: Medium	Low Q: High A: Low C: Medium

Emergence regime is a key factor structuring this (and other) intertidal biotopes although it should be noted that *Corallina officinalis* may occur at a range of shore heights depending on local conditions such as the degree of wave action (Dommasnes, 1969), shore topography, run-off and degree of shelter from canopy forming macroalgae. The rock pool habitat will provide some protection from emergence but increased exposure would lead to an increase in emergence which may lead to shallow pools drying out, greater exposure to air temperatures with corresponding fluctuations in water temperature and changes in salinity following evaporation or dilution by rainfall. Changes in emergence may therefore lead to species replacement and the development of a biotope more typical of the changed shore level.

This biotope is considered sensitive to increased emergence as the key characterizing *Corallina officinalis* is sensitive to desiccation (Dommasnes, 1969) and is generally not found on open rock unless protected by algal canopies or where the surfaces are damp or wet. At Hinkley Point (Somerset, England), for example, seawater run-off from deep pools high in the intertidal supports dense turfs of *Corallina* spp. lower on the shore (Bamber & Irving, 1993). Fronds are highly

intolerant of desiccation and do not recover from a 15% water loss, which might occur within 40-45 minutes during a spring tide in summer (Wiedemann, 1994). Bleached corallines were observed 15 months after the 1964 Alaskan earthquake which elevated areas in Prince William Sound by 10 m. Similarly, increased exposure to air caused by upward movement of 15 cm due to nuclear tests at Armchitka Island, Alaska adversely affected *Corallina pilulifera* (Johansen, 1974). During an unusually hot summer, Hawkins & Hartnoll (1985) observed damaged *Corallina officinalis* and other red algae. Littler & Littler, (1984) suggest that the basal crustose stage is adaptive, allowing individuals to survive periods of physical stress as well as physiological stress such as desiccation and heating. The basal crust stage may persist for extended periods with frond regrowth occurring when conditions are favourable.

Occurrence of encrusting coralline algae seems to be critically determined by exposure to air and sunlight. Colonies survive in damp conditions under algal canopies or in pools but not on open rock where desiccation effects are important. Increased emergence leading to drying out of shallow pools would reduce habitat suitability for this group. Spore release by the crusting coralline *Lithophyllum incrustans* is triggered by small changes in salinity and temperature and therefore changes in emergence may alter patterns in reproduction and recruitment (see relevant pressures for further information). However, this species does occur both high and low in the intertidal (Edyvean & Ford, 1986) and presumably such impacts are limited.

Paracentrotus lividus is typically a sublittoral species (Boudouresque & Verlaque, 2001) and the upper limits of *Paracentrotus lividus* on a shore are limited by desiccation. The rock pool habitat provides some protection but increases in emergence that lead to the drying of shallow pools, greater exposure to air temperatures or increased salinity would negatively impact this species.

Mobile epifauna are likely to relocate to more suitable habitats. Species such as *Littorina littorea* that are found throughout the intertidal zone are adapted to tolerate desiccation to some extent. For example: littorinids can seal their shell using the operculum while limpets clamp tightly to rock reducing water loss.

Corallina officinalis, *Paracentrotus lividus* and many of the associated species are found subtidally. Decreased emergence is likely to lead to the habitat the biotope is found in becoming more suitable for the lower shore species generally found below the biotope, leading to replacement by, for example, a kelp dominated biotope with red algae and *Corallina officinalis and Paracentrotus lividus* surviving under the canopy. Although the key species would be expected to survive the biotope would have altered from the description.

Sensitivity assessment. Emergence is a key factor structuring the distribution of on the shore. Resistance to increased emergence is assessed as 'Medium' as the coralline crusts, *Corallina officinalis* and *Paracentrotus lividus* are intolerant of desiccation but are generally protected by the pool environment. Recovery is assessed as 'High' and sensitivity is therefore assessed as 'Low'. An increase in emergence repositioning the biotope at an upper shore level would be likely to significantly affect the species composition due to increased temperatures, greater variation in salinity and greater sensitivity.

A decrease in emergence would mean that shallow rockpools would be at less risk of desiccation. In addition, depending on the nature of the surrounding bedrock, the rockpool may become slightly deeper. As a result, it is possible that species diversity could increase but, on the whole, biotopes at the upper and mid-shore are likely to be tolerant of a decrease in emergence at the benchmark level. Pre-emption of space by *Corallina officinalis* and other red algae may reduce the

establishment of lower shore species including kelps, resistance is therefore assessed as 'Medium' to decreased emergence and recovery as 'High' so that sensitivity is assessed as 'Low'.

Wave exposure changes (local)	High Q: High A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Low

Colonies of *Lithophyllum incrustans* appear to thrive in conditions exposed to strong water movement. Irvine & Chamberlain (1994) observed that this species is best developed on wave exposed shores. *Corallina officinalis* dominated biotopes are found in a range of flow rates *from* 'moderately strong' (0.5-1.5 m/s) to very 'weak' negligible) (Connor *et al*., 2004; Dommasnes, 1969) and the rock pool habitat of this biotope will provide some protection from water flows. Moderate water movement is beneficial to seaweeds as it carries a supply of nutrients and gases to the plants and removes waste products. However, if flow becomes too strong, plants may become displaced. Additionally, an increase to stronger flows may inhibit settlement of spores and remove adults or germlings. However, *Corallina officinalis* have a compact, turf forming growth which reduce water flow through turbulence and friction and are probably resistant to displacement by an increase in water flow. The shallow burrows created by *Paracentrotus lividus* also provide some protection from dislodgement. Changes in water flow at the pressure benchmark may result in increased or decreased sediment deposition, these are not considered to alter the character of the biotope but may alter species richness of the small invertebrates associated with the turf.

Sensitivity assessment. Wave action rather than water flow is a more significant source or water movement than currents in this biotope. *Corallina officinalis* biotopes are found across a range of flow rates, mid-range populations are considered to have 'High' resistance to a change in water flow at the pressure benchmark (although see sediment supply caveats). Resilience is assessed as 'High', by default, and the biotope is considered 'Not sensitive'.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark may adversely impact the biotope. Little information was found concerning the effects of heavy metals on turf forming and encrusting coralline algae. However, Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg> inorganic Hg > Cu > Ag > Zn> Cd>Pb. Most of the information available suggests that the associated adult gastropod molluscs are rather tolerant of heavy-metal toxicity (Bryan, 1984). Winkles may absorb metals from the surrounding water by absorption across the gills or from their diet, and evidence from experimental studies on *Littorina littorea* suggest that diet is the most important source (Bryan *et al*., 1983). The species has been suggested as a suitable bioindicator species for some heavy metals in the marine environment. Bryan *et al*. (1983) suggested that the species is a reasonable indicator for Ag, Cd, Pb and perhaps As. In the Fal estuary *Patella vulgata* occurs at, or just outside, Restronguet Point, at

the end of the creek where metal concentrations are in the order: Zinc (Zn) 100-2000 µg/l, copper (Cu) 10-100µg/l and cadmium (Cd) 0.25-5µg/l (Bryan & Gibbs, 1983). However, in the laboratory *Patella vulgata* was found to be intolerant of small changes in environmental concentrations of Cd and Zn by Davies (1992). At concentrations of 10µg/l pedal mucus production and levels of activity were both reduced, indicating a physiological response to metal concentrations. Exposure to Cu at a concentration of 100 µg/l for one week resulted in progressive brachycardia (slowing of the heart beat) and the death of limpets. Zn at a concentration of 5500 µg/l produced the same effect (Marchan *et al*., 1999).

Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark may adversely impact the biotope. Where exposed to direct contact with fresh hydrocarbons, encrusting coralline algae appear to have a high intolerance. Crump *et al*. (1999) described "dramatic and extensive bleaching" of '*Lithothamnia*' following the *Sea Empress* oil spill. Observations following the *Don Marika* oil spill (K. Hiscock, pers. comm.) were of rockpools with completely bleached coralline algae. However, Chamberlain (1996) observed that although *Lithophyllum incrustans* was affected in a short period of time by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

Following the *Torrey Canyon* oil spill in 1967, oil and detergent dispersants affected high shore specimens of *Corallina officinalis* more than low shore specimens. Plants in deep pools were afforded some initial protection, although probably later affected by contaminated runoff. In areas of heavy spraying, however, *Corallina officinalis* was killed. (Smith, 1968). Intolerance to hydrocarbon pollution has been assessed to be high, as key structural and important characterizing coralline algal species will be lost and the biotope not be recognized in their absence.

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Contamination by synthetic chemicals, at levels greater than the pressure benchmark may adversely impact the biotope. Smith (1968) reported that oil and detergent dispersants from the *Torrey Canyon* spill affected high water plants of *Corallina officinalis* more than low shore plants and some plants were protected in deep pools. In areas of heavy spraying, however, *Corallina officinalis* was killed (Smith, 1968). Regrowth of fronds had begun within two months after spraying ceased (Smith, 1968). O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction.

Cole *et al*. (1999) suggested that herbicides were (not surprisingly) very toxic to algae and macrophytes. Hoare & Hiscock (1974) noted that with the exception of *Phyllophora* species, all red algae including encrusting coralline forms, were excluded from the vicinity of an acidified

halogenated effluent discharge in Amlwch Bay, Anglesey and that intertidal populations of *Corallina officinalis* occurred in significant amounts only 600 m east of the effluent. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

Most pesticides and herbicides were suggested to be very toxic for invertebrates, especially crustaceans (amphipods isopods, mysids, shrimp and crabs) and fish (Cole *et al.*, 1999).

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence was found to assess this pressure at the benchmark. Algae bioaccumulate radionuclides (with extent depending on the radionuclide and the algae species). Adverse effects have not been reported at low levels.

Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

Nutrient enrichment	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Over geological timescales periods of increased nutrient availability have experienced increases in the distribution of crustose coralline species at the expense of corals (Littler & Littler, 2013), suggesting that this group have some tolerance for enhanced nutrient levels. Overall, Littler and Littler (2013) suggest that corallines as a group can tolerate both low and elevated levels of nutrients. The key characterizing *Corallina officinalis* and the associated green algae species have been identified worldwide as species that occur in areas subject to increased nutrient input within the vicinity of sewage outfalls and at intermediately polluted sites (Littler & Murray, 1975; May, 1985; Brown *et al.*, 1990; Belgrove *et al.*, 1997 and 2010). For example Kindig and Littler (1980) demonstrated that *Corallina officinalis* var. *chilensis* in South California showed equivalent or enhanced health indices, highest productivity and lowest moralities (amongst the species examined) when exposed to primary or secondary sewage effluent. Grazers in the biotope may benefit from increased availability of food resources, due to enhanced growth.

The review by Boudouresque & Verlaque, (2001) considered that *Paracentrotus lividus* are insensitive to nutrient enrichment as dense populations are found in polluted areas. Density of *Paracentrotus lividus* increased towards a sewage outlet in Cortiou cove, France (Boudouresque & Verlaque, 2001). *Paracentrotus lividus* cultivated adjacent to salmon pens exposed to high levels

of nutrients thrived (Cook & Kelly, 2007).

Atalah & Crowe (2010) added nutrients to rockpools occupied by a range of algae including encrusting corallines, turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. The invertebrates present were mostly *Patella ulyssiponensis*, the winkle *Littorina littorea* and the flat top shell *Gibbula umbilicalis*. Nitrogen and phosphorous enhancement was via the addition of fertilisers, as either 40 g/l or 20 g/l. The treatments were applied for seven month and experimental conditions were maintained every two weeks. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. Nutrients had no significant effect on the cover of *Corallina officinalis*. The cover of green filamentous algae was significantly increased both by reduced grazing and increased nutrients, although the effect size was synergistically magnified by the combined effect of grazer removal and nutrients. Nutrient enrichment caused an absolute increase in the average cover of green filamentous algae of 19% (±3.9 S.E.) with respect to the control treatments while the cover of red turfing algae was not affected by nutrient addition (Atalah & Crowe, 2010).

Sensitivity assessment. The pressure benchmark is relatively protective and may represent a reduced level of nutrient enrichment in previously polluted areas. Due to the tolerance of high levels of nutrient input demonstrated generally by Corallina turfs e.g. Bellgrove *et al*., (2010) and Atalah & Crowe, (2010) and *Paracentrotus lividus* (Boudouresque & Verlaque, 2001; Cook & Kelly, 2007). resistance to this pressure is assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'. Where *Corallina* dominated biotopes have replaced canopy forming species in enriched areas it is not clear whether a change to the benchmark would lead to a shift in biotope type. Once established the presence of *Corallina* spp. and other turf forming species may limit recruitment by taller species (Bellgrove *et al*., 2010). No evidence was found to support an assessment of this indirect effect and it is not presented within the table.

Organic enrichment	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No direct evidence was found to assess this pressure. Organic enrichment may lead to eutrophication with adverse environmental effects including deoxygenation, algal blooms and changes in community structure (see nutrient enrichment and de-oxygenation). Where the biotopes occur in tide swept or wave exposed areas (Connor *et al*., 2004) water movements will disperse organic matter reducing the level of exposure. The key characterizing species *Corallina officinalis* has been noted to increase in abundance and may form extensive turfs within the vicinity of sewage outfalls and at intermediately polluted sites (Littler & Murray, 1975; May, 1985; Brown *et al*., 1990; Bellgrove *et al*., 2010). *Corallina elongata* and the crusting coralline *Lithophyllum incrustans* were present at sites dominated by *Ulva* spp. in the Mediterranean exposed to high levels of organic pollution from domestic sewage (Arévalo *et al*., 2007). As turf forming algae *Corallina* spp. trap large amounts of sediment and are therefore not considered sensitive to sedimentation. The turfs host a variety of associated species and deposit feeders amongst these would be able to consume inputs of organic matter.

The review by Boudouresque & Verlaque, (2001) considered that *Paracentrotus lividus* are insensitive to nutrient enrichment as dense populations are found in polluted areas. Density of *Paracentrotus lividus* increased towards a sewage outlet in Cortiou cove, France (Boudouresque & Verlaque, 2001). *Paracentrotus lividus* cultivated adjacent to salmon pens exposed to high levels of particulate organic matter thrived (Cook & Kelly, 2007).

Sensitivity assessment. Based on resistance to sedimentation, exposure to wave action, the presence of detrital consumers and the persistence of turfs and *Paracentrotus lividus* in areas subject to sewage inputs resistance is assessed as 'High' and resilience as 'High' (by default). The biotope is therefore considered to be 'Not sensitive' to this pressure at the benchmark.

Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). Sensitivity within the direct spatial footprint of this pressure is therefore 'High'. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

This biotope is characterized by the hard rock substratum to which the characterizing encrusting corallines and *Corallina* turf and associated species, can firmly attach to, in the case of *Paracentrotus lividus* on limestone, burrow into. Changes to a free draining sediment type or to an impervious artificial substratum that was free draining would significantly alter the character of the biotope through the loss of the pool habitat. A change to an artificial substratum could also impact the development of this biotope as species may have settlement preferences for particular surface textures. *Corallina officinalis* shows optimal settlement on finely rough artificial substrata (0.5 - 1 mm surface particle diameter). Although spores will settle and develop as crustose bases on smooth surfaces, fronds were only initiated on rough surfaces. *Corallina officinalis* settled on artificial substrata within one week in the field in summer months in New England (Harlin & Lindbergh 1977). However, in the laboratory fronds can grow from bases attached to smooth surfaces (Wiedeman pers comm. Previous MarLIN review).

Paracentrotus lividus occurs in a range of habitats on solid rocks, boulders and in meadows of sea grasses but is uncommon on sand and other sediment types (Boudouresque & Verlaque, 2001). *Paracentrotus lividus* burrows into sandstone, limestone basalt and granite but not hard slate (Boudouresque & Verlaque, 2001), other artificial hard substratum may not be suitable for burrows.

Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al*., 2012; Firth *et al*., 2013) or the presence of non-native species (Bulleri & Airoldi, 2005).

Sensitivity assessment. The biotope is considered to have 'No' resistance to this pressure based on a change to a soft sediment substratum or a hard, free draining substratum. Recovery is 'very Low' as the change at the benchmark is permanent. Sensitivity is therefore assessed as 'High'.

Physical change (to another sediment type)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant to biotopes occurring on bedrock.

Habitat structure changes - removal of substratum (extraction)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The species characterizing this biotope are epifauna or epiflora occurring on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be 'Not relevant' to hard substratum habitats.

Abrasion/disturbance of the surface of the substratum or seabed	Medium Q: High A: High C: High	High Q: High A: Low C: Medium	Low Q: High A: High C: Low

The species characterizing this biotope occur on the rock and therefore have no shelter from abrasion at the surface. Littler & Littler, 1984) suggest that the basal crustose stage of *Corallina officinalis* is adaptive to resist sand scour and wave shearing (as well as physiological stressors such as desiccation and heating). The base is much tougher than the fronds shown by experiments that have demonstrated that the base has nearly twice the mechanical resistance (measured by penetration) of fronds (Littler & Kauker, 1984).

In general, studies show that *Corallina* and other turf forming algae appear to be relatively resistant to single events and low levels of trampling. Brosnan & Crumrine (1994), for example, found that in experimentally trampled plots the cover of foliose and canopy forming species declined while turf forming algae were relatively resistant. Similarly, a comparison of rocky intertidal ledges that received different amounts of visitors in Dorset, England, found that *Corallina officinalis* were present on both heavily visited and less visited ledges suggesting that this species has some resistance to trampling (Pinn & Rodgers, 2005). Povey & Keough (1991) in Mornington Peninsula, Australia investigated the effects of sustained trampling on intertidal coralline algal mats where upright branching *Corallina* spp. formed a turf with other red algae with sand and encrusting coralline algae between turfs. The experimental strips were 2 m long and 0.5 m wide. The percentage cover of upright *Corallina* spp. was significantly affected by 25 passages of a strip per day after 12 and 33 days. The algae appeared flattened and were shorter (1-2 cm high) compared with the low intensity and control plots (3-4 cm high). However low intensity trampling within a strip (2 passages/ day) did not significantly affect the coralline turf.

Brown & Taylor (1999) also found that higher intensities of trampling damaged turfs. Moderate (50 steps per 0.09 sq. metres) or more trampling on intertidal articulated coralline algal turf in New Zealand reduced turf height by up to 50%, and weight of sand trapped within turf to about one third of controls. This resulted in declines in densities of the meiofaunal community within two days of trampling. Although the community returned to normal levels within 3 months of trampling events, it was suggested that the turf would take longer to recover its previous cover (Brown & Taylor 1999). Similarly, Schiel & Taylor (1999) noted that trampling had a direct detrimental effect on coralline turf species on the New Zealand rocky shore. At one site coralline bases were seen to peel from the rocks (Schiel & Taylor 1999), however, this was probably due to increased desiccation caused by loss of the algal canopy.

Schiel & Taylor (1999) reported the death of encrusting corallines one month after trampling due to removal of their protective canopy of fucoids by trampling (10 -200 tramples where one trample equals one transect walked by one person). A higher proportion of corallines died back in spring treatments presumably due to the higher levels of desiccation stress expected at this time of year. However, encrusting corallines increased within the following year and cover returned to control levels within 21 months (Schiel & Taylor, 1999). Mechanical abrasion from scuba divers was also reported to impact encrusting corallines, with cover of *Lithophyllum stictaeforme* greater in areas where diving was forbidden than visited areas (abundance, 6.36 vs 1.4; it is presumed this refers to proportion of cover, although this is not clear from the text, Guarinieri *et al*., 2012).

Dethier (1994) experimentally manipulated surface abrasion on a range of encrusting algae including *Lithophyllum impressum*. Crusts were brushed with either a nylon or steel brush for 1 minute a month for 24 months. Unbrushed controls grew by approximately 50% where the cover of nylon brushed crusts and steel brushed crusts decreased by approximately 25% and 40% respectively (interpreted from figures in Dethier, 1994). In laboratory tests on chips of *Lithophyllum impressum* brushing with a steel brush for 1 minute once a week for 3 weeks, resulted in no cover loss of two samples while a third 'thinned and declined' (Dethier, 1994).

The burrows of *Paracentrotus lividus* may provide some protection from abrasion. No direct evidence was found to assess sensitivity. MacDonald *et al*. (1996) assessed benthic species sensitivity to fishing disturbance by 'scoring' each species ability to withstand the physical impact of a single fishing disturbance and recovery potential assuming no further fishing disturbance occurred. These authors classified the larger urchin slow growing *Echinus esculentus* as being 'very fragile'. Kaiser *et al*. (2000) reported that *Echinus esculentus* were less abundant in areas subject to high trawling disturbance in the Irish Sea. This species was reported to suffer badly as a result of impact with passing scallop or queen scallop dredges (Bradshaw *et al*., 2000; Hall-Spencer & Moore, 2000a), it is likely that when directly exposed to abrasion *Paracentrotus lividus* would be similarly impacted.

No evidence was found for the sensitivity of the small invertebrates associated with the coralline turf but abrasion could displace and damage these. The littorinids and top shells that occur in this biotope, have some protection from hard shells but abrasion may damage and kill individuals Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victoria, Australia, found that in single step experiments less than 5% of littorinids were crushed in single step experiments (Povey & Keough, 1991).In sites with mobile cobbles and boulders increased scour results in lower densities of *Littorina* spp. compared with other, local sites with stable substratum (Carlson *et al*., 2006).

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on evidence from the step experiments and the relative robustness of the encrusting corallines and *Corallina officinalis* turf and associated species, resistance, to a single abrasion event is assessed as 'Medium' and recovery as 'High', so that sensitivity is assessed as 'Low'. Resistance and resilience will be lower (and hence sensitivity greater) to abrasion events that exert a greater crushing force and remove the bases than the trampling examples the assessment is based on). The sensitivity of the key characterizing species *Paracentrotus lividus* is likely to be greater when directly exposed to abrasion. Resistance is therefore assessed as 'Low' and recovery as 'Medium' so that the sensitivity of the biotope defined by this species is assessed as 'Medium'.

Penetration or disturbance of the substratum subsurface	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The species characterizing this biotope group are epifauna and epiflora occurring on rock which is resistant to subsurface penetration. The assessment for abrasion at the surface only is therefore considered to equally represent sensitivity to this pressure.

Changes in suspended solids (water clarity)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Intertidal biotopes will only be exposed to this pressure when submerged during the tidal cycle and thus have limited exposure. Siltation, which may be associated with increased suspended solids and the subsequent deposition of these is assessed separately (see siltation pressures). In general, increased suspended particles reduce light penetration and increase scour and deposition. They may enhance food supply to filter or deposit feeders (where the particles are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts).

Increases in the cover of sediment trapping, turf forming algae at the expense of canopy forming species has been observed worldwide in temperate systems and has been linked to increased suspended solids linked to human activities worldwide (Airoldi, 2003). *Corallina* species accumulate more sediment than any other alga (Hicks, 1985). Hence an increase in suspended sediment is likely to accumulate in the coralline turf. A significant increase may result in smothering (see above). An accumulation of sediment within the turf may attract more sediment dwelling interstitial invertebrates such as nematodes, harpacticoids and polychaetes, although in more wave exposed locations accumulation of sediment is likely to be minimal. Increased suspended sediment may also result in increased scour, which may adversely affect foliose red algae, and interfere with settling spores and recruitment if the factor is coincident with their major reproductive period. However, coralline algae, especially the crustose forms are thought to be resistant of sediment scour (Littler & Kauker, 1984), and will probably not be adversely affected at the benchmark level.

No direct evidence was found for the sensitivity of *Paracentrotus lividus* to changes in suspended solids. However this species has been reported to increase in abundance at sites subject to organic pollution where levels of particulate organic matter are high. Density of *Paracentrotus lividus* increased towards a sewage outlet in Cortiou cove (Boudouresque & Verlaque, 2001, references therein). *Paracentrotus lividus* cultivated adjacent to salmon pens that received high levels of particulate organic matter thrived (Cook & Kelly, 2007).

This community is unlikely to be dependent on suspended sediment. Although accumulated sediment within coralline turf habitats is likely to increase the species diversity of the epiphytic fauna, in very wave exposed locations, accumulated sediment in the habitat is likely to be minimal. A reduction in suspended sediment will probably reduce the risk of scour, and reduce food availability for the few suspension feeding species in the biotope (e.g. barnacles and spirorbids present), although effects are not likely to be lethal.

The biotope occurs in shallow waters where light attenuation due to increases in turbidity is probably low. Red algae and coralline algae especially are known to be shade tolerant and are

common components of the understorey on seaweed dominated shores. Limited shading from suspended sediments is therefore not considered to negatively affect this genus. Therefore, a decrease in light intensity is unlikely to adversely affect the biotope. An increase in light intensity is unlikely to adversely affect the biotope as plants can acclimate to different light levels.

Sensitivity assessment. The exposure of biotope to suspended sediments in the water column will be limited to immersion periods, and wave action will reduce accumulation. The biotope is considered to be 'Not sensitive' to a reduction in suspended solids, although this may reduce food supply to the barnacles and other filter feeders that occur in this biotope. An increase in suspended solids may lead to some sub-lethal abrasion of fronds however, evidence globally indicates that increase suspended solids favour the turf-forming algae that characterize this biotope (Airoldi, 2003). Resistance is therefore assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'.

Smothering and siltation rate changes (light)

Low	Medium	Not sensitive
Q: High A: Low C: Low	Q: High A: Low C: Medium	Q: High A: Low C: Low

Increased abundance of algal turfs worldwide has been linked to sediment perturbations although not all the pathways and mechanisms of these effects are clear (see review by Airoldi, 2003). However, even the most tolerant of organisms would eventually suffer from inhibition and mortality following smothering although the thresholds for these effects have not been identified (Airoldi, 2003). *Corallina officinalis* and others within the genus (e.g. *Corallina pinnatifolia* and *Corallina vancouveriensis*) are found on shores subject to high rates of sedimentation that are periodically disturbed by sand burial and scour (Stewart, 1989). Coralline turfs also trap sediments within the turf. The amount of sediment present and the associated fauna varies naturally depending on local conditions such as wave exposure (Dommasnes, 1969). On intertidal shores in southern California the amount of sediment trapped within turfs of *Corallina* spp. varied seasonally (from < 5 mm to >4.5 cm) and was closely related to species composition and the structure of the turf. Airoldi (2003) identified a number of morphological, physiological and life history traits that conferred high levels of tolerance to sedimentation. Those shared by *Corallina* spp are the regeneration of upright fronds from a perennial basal crust resistant to burial and scour, calcified thalli, apical meristems, large reproductive ouptuts, lateral vegetative growth and slow growth rates (Airoldi, 2003).

In a review of the effects of sedimentation on rocky coast assemblages, Airoldi (2003) outlined the evidence for the sensitivity of coralline algae to sedimentation. The reported results are contradictory with some authors suggesting that coralline algae are negatively affected by sediments while others report that encrusting corallines are often abundant or even dominant in a variety of sediment impacted habitats (Airoldi, 2003 and references therein). Crustose corallines have been reported to survive under a turf of filamentous algae and sediment for 58 days (the duration of experiment) in the Galapagos (species not identified, Kendrick, 1991). The crustose coralline *Hydrolithon reinboldii*, has also been reported to survive deposition of silty sediments on subtidal reefs off Hawaii (Littler, 1973).

Atalah & Crowe (2010) added sediment to rockpools in controlled experiments that appear to be very similar to this biotope. The rockpools were occupied by a range of algae including encrusting corallines, turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. The invertebrates present were mostly *Patella ulyssiponensis*, the winkle *Littorina littorea* and the flat top shell *Gibbula umbilicalis*. Sediment treatment involved the addition of a

mixture of coarse and fine sand of either 300 mg/cm^2/month or 600 mg/cm^2 every 15 days (the depth of sediment was not reported). The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. In the pools the chronic addition of both levels of sediment led to a significant decrease in grazers and crustose coralline algae also decreased. Sedimentation had no significant effect on the cover of green filamentous algae (*Ulva* sp.) but led to an increase in the mean cover of red turfing algae (*Mastocarpus stellatus* and *Chondrus crispus* and *Corallina officinalis*) from 11.7% (±1.0 S.E.) in controls to 26.1% (±4.7 S.E.) in sedimented assemblages, but there were no differences between the two levels of sedimentation. The cover of red filamentous algae (*Ceramium* spp. *Gelidium* spp.) was also significantly increased in the sedimentation experiments. The experimental results support the general trend of greater sensitivity of grazers and encrusting corallines to sedimentation than turf-forming algae.

No direct evidence was found to support this assessment for *Paracentrotus lividus*. Last *et al*., (2011) found that another epifaunal urchin *Psammechinus miliaris* is moderately tolerant of shorter term (12 days) burial events, with less than 25% mortality of all buried specimens. Survivorship was partly due to the re-emergence of many specimens, even from depths of up to 7cm, particularly when buried under coarse sediment. After 12 days of burial, mortality in the specimens that remained buried was high. Percentage mortality increased with progressively finer sediment fractions (Last *et al*., 2011).

Sensitivity assessment. Where sediments are added to tide pools they may be removed rapidly in wave exposed environments where pools are flushed or they may remain in-situ increasing the level of exposure. These effects are site specific and will mediate the level of impact. Within the biotope the associated urchins and encrusting corallines are probably the most sensitive element, littorinids may also be negatively impacted but his will depend on the character of the deposit. Where grazing is reduced then the algal assemblage is likely to change. The encrusting corallines may be sensitive to sedimentation but the level of sensitivity is difficult to ascertain from the evidence base. The turf-forming species are generally tolerant of some sedimentation but the threshold in relation to the benchmark is not easily determined, especially as this biotope occurs in rockpools which may increase the exposure. The encrusting corallines are considered to have 'Low' resistance to this pressure and 'Medium' resilience, while the algal turf and *Paracentrotus lividus* is considered to have 'Medium' resistance and 'High' resilience. The more precautionary assessment of 'Medium' sensitivity is presented in the sensitivity assessment table.

Smothering and siltation rate changes (heavy)	None Q: Low A: NR C: NR	Medium Q: High A: Low C: Medium	Medium Q: Low A: Low C: Low

The available evidence for siltation pressures is outlined for the 'light' deposition pressure. At the pressure benchmark 'heavy deposition' represents a considerable thickness of deposit and may fill shallow pools. Complete burial of algal turf and encrusting corallines and associated animals would occur. Removal of the sediments by wave action and tidal currents would result in considerable scour. The effect of this pressure is likely to be mediated by the length of exposure to the deposit. Resistance is assessed as 'Low' to 'None' as the impact is likely to be significant and would almost certainly result in the loss of grazers and a high proportion of the encrusting corallines. Resilience is assessed as 'Medium' and sensitivity is assessed as 'Medium'.

Litter	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

Not assessed.

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

Underwater noise changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant

Introduction of light or shading	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Coralline crusts and Corallina officinalis are shade tolerant algae, often occurring under a macralgal canopy that reduces light penetration. These species can acclimate to different levels of light intensity and quality and encrusting corallines can occur in deeper water than other algae where light penetration is limited. Samples of *Lithophyllum impressum* suspended from a raft and shaded (50-75% light reduction) continued to grow over two years (Dethier, 1994). In areas of higher light levels, the fronds and bases may be lighter in colour due to bleaching (Colhart & Johansen, 1973). Other red algae in the biotope are flexible with regard to light levels and can also acclimate to different light levels. Canopy removal experiments in a rocky sub tidal habitat in Nova Scotia, Canada by Schmidt and Scheibling (2007) did not find a shift in understorey macraoalgal turfs (dominated by *Corallina officinalis*, *Chondrus crispus* and *Mastocarpus stellatus*) to more light-adapted species over 18 months.

Bright light and shading elicit well studied reactions in echinoderms. In echinoids shading results in the 'shadow reaction' in which the pedicellariae and spines are pointed in the direction of the shade in a defensive reaction. Echinoids move away from bright light and seek out crevices and / or cover themselves with debris such as shells and drift algae, the 'covering reaction' (see Boolootian (1966) for discussion). An increase in light may therefore lead to more covering by *Paracentrotus lividus*.

Sensitivity assessment. As the key structuring and characterizing species colonize a broad range of light environments from intertidal to deeper sub tidal and shaded understorey habitats the biotope is considered to have ‘High’ resistance and, by default, ‘High’ resilience and therefore is ‘Not sensitive’ to this pressure.

Barrier to species movement	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. Barriers and changes in tidal excursion are not considered relevant to the characterizing *Corallina officinalis* as species dispersal is limited by the rapid rate of settlement and vegetative growth from bases rather than reliance on recruitment from outside of populations. Other species associated with the biotope such as *Paracentrotus*

lividus produce large numbers of larvae capable of long distance transport and survival, resistance to this pressure is assessed as 'High' and resilience as 'High' by default. This biotope is therefore considered to be 'Not sensitive'.

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant' to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Bright light and shading elicit well studied reactions in echinoderms. In echinoids shading results in the 'shadow reaction' in which the pedicellariae and spines are pointed in the direction of the shade in a defensive reaction. Echinoids move away from bright light and seek out crevices and / or cover themselves with debris such as shells and drift algae, the 'covering reaction' (see Boolootian (1966) for discussion). Movement of boats is unlikely to be noticed, if echinoids react to the approach of divers and snorkelers at closer proximity, the reaction is likely to be short lived and insignificant.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Paracentrotus lividus cultivation occurs in some of its range. The key characterizing species *Paracentrotus lividus* is cultivated commercially from hatchery reared individuals, this practice is relatively recent and no evidence was found to assess potential impact of gene flow between wild and cultivated populations. Due to the wide dispersal of the larval there appears to be much gene flow and mixing between populations with little genetic variation (Duran *et al*., 2004; Luri *et al*., 2007).

Commercial cultivation of *Mytilus edulis* (which occurs in low densities in this biotope) involves the collection of juvenile mussel 'seed' or spat (newly settled juveniles ca 1-2 cm in length) from wild populations, with subsequent transportation around the UK for re-laying in suitable habitats. As the seed is harvested from wild populations from various locations the gene pool will not necessarily be decreased by translocations. Movement of mussel seed has the potential to transport pathogens and non-native species (see sensitivity assessments for *Mytilus edulis* bed biotopes). A review by Svåsand *et al*. (2007) concluded that there was a lack of evidence distinguishing between different *Mytilus edulis* populations to accurately assess the impacts of hybridisation with the congener *Mytilus galloprovincialis* and in particular how the gene flow may be affected by aquaculture. Therefore, it cannot be confirmed whether farming will have an impact on the genetics of wild sindividuals beyond a potential for increased hybridisation.

Sensitivity assessment. No direct evidence was found regarding the potential for negative impacts

of translocated mussel seed on wild *Mytilus edulis* populations. While it is possible that translocation of mussel seed could lead to genetic flow between cultivated beds and local wild populations, there is currently no evidence to assess the impact (Svåsand *et al.*, 2007). Gene flow between populations of *Paracentrotus lividus* is high due to the long range dispersal and there is little genetic differentiation between populations. Resistance of this species and the biotope it defines is therefore assessed as 'High', resilience is 'High' (by default) and the biotope is 'Not sensitive'.

Introduction or spread of invasive non-indigenous species	Low	Very Low	High
	Q: Low A: NR C: NR	Q: High A: High C: High	Q: Low A: Low C: Low

Within rockpools temperature and salinity may be subject to rapid variation and these conditions will largely exclude species that are adapted to more stable, subtidal environments. Invasive non-indigenous species (INIS) that can alter habitats (ecological engineers), or out-compete native macroalgae for space and other resources such as light and nutrients, are the most likely species to negatively affect this biotope. Space pre-emption by encrusting corallines and the crustose bases of the macroalgae forming the turf, as well as the trapped sediment within the turf, may prevent settlement of INIS until disturbance events create gaps for invasion. However, in the Mediterranean crustose corallines and algal turfs facilitate attachment of *Caulerpa racemosa* by providing a more complex substratum than bare rock (Bulleri & Benedetti-Cecchi, 2008).

Algal species which may have overlapping habitat requirements include the green seaweed *Codium fragile* ssp. *tormentosoides* (now renamed as *Codium fragile fragile*) and the red seaweed *Heterosiphonia japonica*, neither of these have so far been recorded in nuisance densities (Sweet, 2011j). Beneath a canopy of the invasive *Codium fragile* ssp. *tomentosoides* on subtidal rocky shores in Nova Scotia, *Corallina officinalis* was the dominant species comprising 78-80% of the turf biomass, while *Chondrus crispus* and *Mastocarpus stellatus* comprised 18% (Schmidt & Scheibling, 2007). The biomass of *Corallina officinalis* was similar to those under a canopy of the native *Laminaria species* on the same shore (*Laminaria longicruris* and *Laminaria digitata*), suggesting little negative effect on turf forming algae. Wireweed, *Sargassum muticum*, grows best on sheltered shores and in rockpools (Sewell, 2011c), where this species dominates rockpools the character of the biotope will be different to the description and the biotope would be reclassified as LR.FLR.Rkp.FK.Sar. The red seaweeds *Heterosiphonia japonica* and *Neosiphonia harveyi* may also occur in this biotope but again no impacts have been reported.

The red seaweed *Grateloupia turuturu* occurs on the lower shore in pools. No ecosystem impacts have been reported in Great Britain; however this large, fast-growing seaweed may have the potential to displace native seaweed species and shade neighbouring species. In North America this species is a major competitor of *Chondrus crispus* which provides an important winter food source for littorinids and other invertebrates. As *Grateloupia turuturu* dies-back in the winter, the dispolacement of other species may therefore affect grazers (Sweet, 2011g).

The tunicates *Didemnum vexillum* and *Asterocarpa humilis*, the hydroid *Schizoporella japonica* and the bryozoan *Watersipora subatra* (Bishop, 2012c, Bishop, 2015a and b; Wood, 2015) are currently only recorded from artificial hard substratum in the UK and it is not clear what their established range and impacts in the UK would be. *Didemnum vexillum* occurs in tide pools in other areas where it has become established (Bishop, 2012c) and can have substantial effects on communities, similarly the tunicates *Corella eumyota* and *Botrylloides violaceus* can smother rock habitats (Bishop, 2011b and 2012b). A significant potential INIS is the Pacific oyster *Magallana gigas*, as its

distribution and environmental tolerances are considered to overlap with this biotope and this reef forming species can alter habitat structure. This species may also affect the grazers present in the biotope. No evidence was found for effects on rock pools, although on the Mediterranean coast *Magallana gigas* is cultivated in micro-tidal lagoons and has established wild populations (Miossec *et al*., 2009, cited from Herbert *et al*., 2012). In the Wadden Sea and North Sea, *Magallana gigas* overgrows mussel beds in the intertidal zone (Diederich, 2005, 2006; Kochmann *et al*., 2008), although larvae did show preference for settling on conspecifics before the mussels, and struggled to settle on mussels with a fucoid covering. It has been observed that mussel beds in the Wadden Sea that are adjacent to oyster farms were quickly converted to oyster beds (Kochmann *et al*., 2008). Dense aggregations of *Magallana gigas* on a former mussel bed showed increased abundance and biomass of *Littorina littorea* in the Wadden Sea (Markert *et al*., 2010). However, Eschweiler and Buschbaum (2011) found that juvenile *Littorina littorea* could carry *Magallana gigas* and *Crepidula fornicata* as epibionts. Body dry weight of snails without oyster overgrowth was twice as high compared to winkles covered with oysters. Also crawling speed of snails with oyster epigrowth was significantly slowed down and about ten times lower than in unfouled periwinkles. Additionally, oyster epibionts caused a strong decrease in reproductive output. In laboratory experiments, egg production of fouled *Littorina littorea* was about 100-fold lower than in affected individuals. Field surveys in different years and habitats demonstrated that up to 10% of individuals occurring on epibenthic bivalve beds and up to 25% of snails living on sand flats may be fouled by *Magallana gigas*.

The non-native crab *Hemigrapsus sanguineus* has recently been recorded in the UK (Sweet & Sewell, 2014) and has the potential to be a significant predator of intertidal invertebrates. Significant reductions in common shore crab abundance and mussel density have been reported where the Asian shore crab has achieved high densities in mainland Europe (Sweet & Sewell, 2014). In Rye, New York, declines of approximately 80% of *Littorina littorea* in the intertidal were reported to coincide with an expansion of the *Hemigrapsus sanguineus* population (Kraemer *et al*., 2007). This crab occurs on exposed shores and may therefore occur in this biotope when established. If predation of littorinids was significantly increased this could impact the algal composition and abundance of this biotope by altering the level of grazing pressure.

Sensitivity assessment. Little evidence was found to assess the impact of INIS on this biotope and much of the evidence comes from intertidal habitats in other countries. The conversion of this biotope to a *Magallana gigas* reef would present a significantly negative impact. Replacement of red algal turfs by other similar species may lead to some subtle effects on local ecology but at low abundances the biotope would still be recognisable from the description. An increase in *Sargassum muticum* would lead to reclassification to the specific biotope. Based on *Magallana gigas* and *Sargassum muticum*, resistance to this pressure is assessed as 'Low'. The biotope will only recover if these species are removed, either through active management or natural processes. To recognise that recovery may be prolonged, resilience is assessed as 'Very Low' and sensitivity is therefore assessed as 'High'.

Introduction of microbial pathogens	Low Q: High A: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Several coralline and non-coralline species are epiphytic on *Corallina officinalis*. Irvine and Chamberlain (1994) cite tissue destruction caused by *Titanoderma corallinae*. However, no information on pathogenic organisms in the UK was found. In Rhodophycota, viruses have been identified by means of electron microscopy (Lee, 1971) and they are probably widespread.

However, nothing is known of their effects on growth or reproduction in red algae and experimental transfer from an infected to an uninfected specimen has not been achieved (Dixon & Irvine, 1977). *Corallina officinalis*, like many other algal species has been demonstrated to produce antibacterial substances (Taskin *et al*., 2007).

Diseased encrusting corallines were first observed in the tropics in the early 1990's when the bacterial pathogen Coralline Lethal Orange Disease (CLOD) was discovered (Littler & Littler, 1995). All species of articulated and crustose species tested to date are easily infected by CLOD and it has been increasing in occurrence at sites where first observed and spreading through the tropics. Another bacterial pathogen causing a similar CLOD disease has been observed with a greater distribution and a black fungal pathogen first discovered in American Samoa has been dispersing (Littler & Littler, 1998). An unknown pathogen has also been reported to lead to white 'target-shaped' marks on corallines, again in the tropic (Littler *et al*., 2007). No evidence was found that these are impacting temperate coralline habitats.

Sea urchins are susceptible to 'bald-sea-urchin disease', which causes lesions, loss of spines, tube feet, pedicellariae, destruction of the upper layer of skeletal tissue and death. The disease has been associated with mass mortalities of *Paracentrotus lividus* in the French Mediterranean with the estimated loss of between 10 and 74% of populations re-surveyed (Boudouresque *et al*., 1980). An investigation by Becker *et al*. (2008) concluded that opportunistic bacteria in the water column are responsible for the symptoms of this disease.

Other species associated with this biotope such as littorinids and other algae also experience low levels of infestation by pathogens but mass-mortalities have not been recorded. For example, parasitism by trematodes may cause sterility in *Littorina littorea*. *Littorina littorea* are also parasitized by the boring polychaete, *Polydora ciliata* and *Cliona* sp, which weakens the shell and increases crab predation. Outbreaks of the shellfish pathogen *Martelia* spp. may cause widespread mortality of *Mytilus edulis* (Mainwaring *et al*., 2014) but populations within the UK have not been significantly impacted.

Sensitivity assessment. Based on the available evidence the characterizing coralline crusts and *Corallina officinalis* biotope is considered to have 'High' resistance and hence 'High' resilience and is classed as 'Not sensitive' at the pressure benchmark. However, where the biotope is defined by the presence of *Paracentrotus lividus*, an outbreak of bacterial pathogens may lead to mass mortalities and subsequent changes in algal abundance and composition. In that instance biotope resistance is assessed as 'Low' and resilience as 'Medium', sensitivity is therefore assessed as 'Medium'. The assessment based on *Paracentrotus lividus* is presented in the sensitivity assessment table.

Removal of target species	Low Q: High A: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. The key characterizing and structuring species *Corallina officinalis* is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al*., 1987). It is also sold as a powder for use in the cosmetic industry. Some species present in the biotope may also be targeted. The blue mussel *Mytilus edulis* is too small and patchy in this biotope to be targeted for commercial harvesting. However, some, unregulated recreational hand-gathering of this

species may occur.

The key characterizing species *Paracentrotus lividus* is harvested commercially in Europe and in Ireland. Populations in Ireland have been depleted (Byrne, 1990; Moylan, 1997) and although some variation in recruitment may contribute the probable cause is overfishing (Andrews *et al*., 2002). As individuals are large, easily visible in the pools they inhabit and have limited mobility collectors will have little difficulty removing populations of suitably sized individuals from pools. Recently *Himanthalia elongata*, *Fucus serratus* and other brown seaweeds have colonized new areas of Lough Hyne (Northern Ireland) following the mass mortality of the *Paracentrotus lividus* (Trowbridge *et al*., 2013), demonstrating the effects that targeted removal of large numbers of this species could have on biotope character.

Littorinids are one of the most commonly harvested species of the rocky shore. Large scale removal of *Littorina littorea* may allow a proliferation of opportunistic green algae, such as *Ulva*, on which it preferentially feeds. Experiments designed to test the effects of harvesting by removing individuals at Strangford Lough found that there was no effect of experimental treatments (either harvesting or simulated disturbance) on *Littorina littorea* abundance or body size over a 12 week period (Crossthwaite *et al*., 2012). This suggests that these animals are generally abundant and highly mobile; thus, animals that were removed were quickly replaced by dispersal from surrounding, un-harvested areas. However, long-term exploitation, as inferred by background levels of harvest intensity, did significantly influence population abundance and age structure (Crossthwaite *et al*., 2012). A broadscale study of harvesting in Ireland using field studies and interviews with wholesalers and pickers did suggest that some areas were over harvested but the lack of background data and quantitative records make this assertion difficult to test (Cummins *et al*., 2002). Similarly experimental grazer removal (manual removal of all gastropods, including *Littorina littorea*, in pool and a 1 m surrounding perimeter) caused strong and highly significant changes in assemblage structure in rockpools that contained red turf forming algae mainly due to an increase in the cover of green filamentous algae and a decrease in cover of live crustose coralline algae (25.40%) (Atalah & Crowe, 2010). Red and green algae may also be collected, *Mastocarpus stellatus*, for example is harvested to produce carrageen.

Sensitivity assessment. Collection of the key characterizing species would significantly alter the character and structure of the biotope and result in the loss of species inhabiting the turf. Collection of the urchin *Paracentrotus lividus* and/or littorinid grazers may allow red and green algae to increase in abundance and density, resulting in the biotope differing from the description. However, these algae may also be subject to harvesting limiting their dominance. The resistance of this biotope to targeted harvesting of characterizing and associated species is 'Low' as the species are all relatively large, conspicuous and easily collected. Resilience is assessed 'Medium' and sensitivity is assessed as 'Medium'.

Removal of non-target species	Low Q: Low A: NR C: NR	Medium Q: High A: Low C: Medium	Medium Q: Low A: Low C: Low

Incidental removal of the key characterizing species and associated species would alter the character of the biotope. The biotope is characterized by dense turfs of *Corallina officinalis*, these provide habitat and attachment surfaces for epiphytic species and where these trap sediments also provide a habitat for associated species. The loss of the turf due to incidental removal as by-catch would therefore alter the character of the habitat and result in the loss of species richness. The ecological services such as primary and secondary production provided by the

characterizing and associated species would also be lost.

Removal of grazers, including the key characterizing *Paracentrotus lividus* could result in changes in algal composition with an increase in macroalgal abundance and/or species present, leading to reclassification of the biotope. Recently, *Himanthalia elongata*, *Fucus serratus* and other brown seaweeds have colonized new areas of Lough Hyne (Northern Ireland) following the mass mortality of *Paracentrotus lividus* (Trowbridge *et al*., 2013). Similarly, experimental grazer removal (manual removal of all gastropods in pool and a 1m surrounding perimeter) caused strong and highly significant changes in assemblage structure in rockpools that contained red turf forming algae mainly due to an increase in the cover of green filamentous algae and a decrease in cover of live crustose coralline algae (25.40%) (Atalah & Crowe, 2010).

Sensitivity assessment. Removal of a large percentage of the characterizing turf and encrusting coralline algae species and grazers would alter the character of the biotope, species richness and ecosystem function. Resistance is therefore assessed as ‘Low’ and recovery as ‘Medium’, so that sensitivity is assessed as 'Medium'.

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